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(54) **BIPOLAR SECONDARY BATTERY**

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H01M 2/26	(2006.01)
H01M 10/0585	(2010.01)
H01M 2/34	(2006.01)

(52) **U.S. Cl.**

CPC ***H01M 10/0418*** (2013.01); ***H01M 2/0207*** (2013.01); ***H01M 2/266*** (2013.01); ***H01M 2/345*** (2013.01); ***H01M 10/0585*** (2013.01); *H01M 2/34* (2013.01)

(58) **Field of Classification Search**

CPC H01M 2/34; H01M 2/345; H01M 2/348; H01M 10/0418

USPC 429/61

See application file for complete search history.

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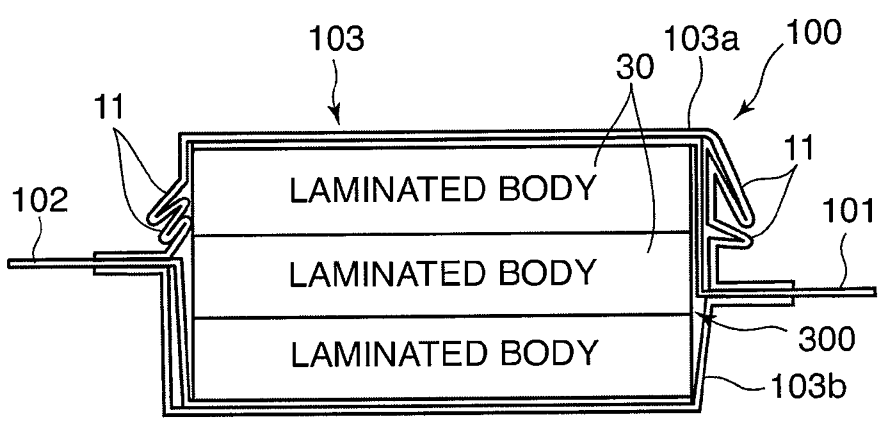
(74) *Attorney, Agent, or Firm* — Foley & Lardner LLP

(57) **ABSTRACT**

A battery main body housed in a case comprises one laminated body composed of a plurality of bipolar electrodes laminated with an electrolyte layer therebetween or comprises a plurality of laminated bodies connected in series. A positive electrode current collecting plate and a negative electrode current collecting plate each having one surface joined to the inner peripheral surface of the case and the other surface joined to one end of the battery main body respectively extend to the outside of the case. By providing a cutoff mechanism for cutting off an electrical connection between the positive electrode current collecting plate and the negative electrode current collecting plate via the battery main body according to an expansion deformation of the case, a current path in a bipolar secondary battery is interrupted when the short-circuit current occurs, thereby protecting the bipolar secondary battery from a short-circuit current.

7 Claims, 8 Drawing Sheets



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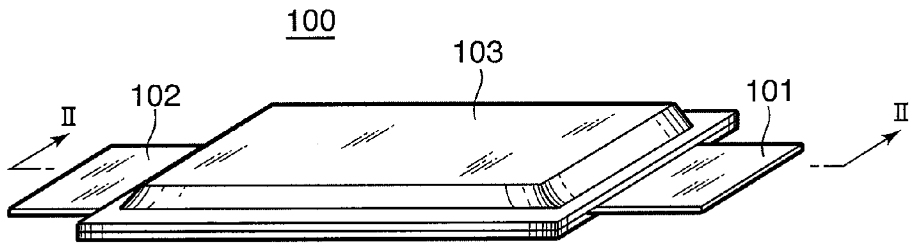
100
103
102
101
II
II

FIG. 1

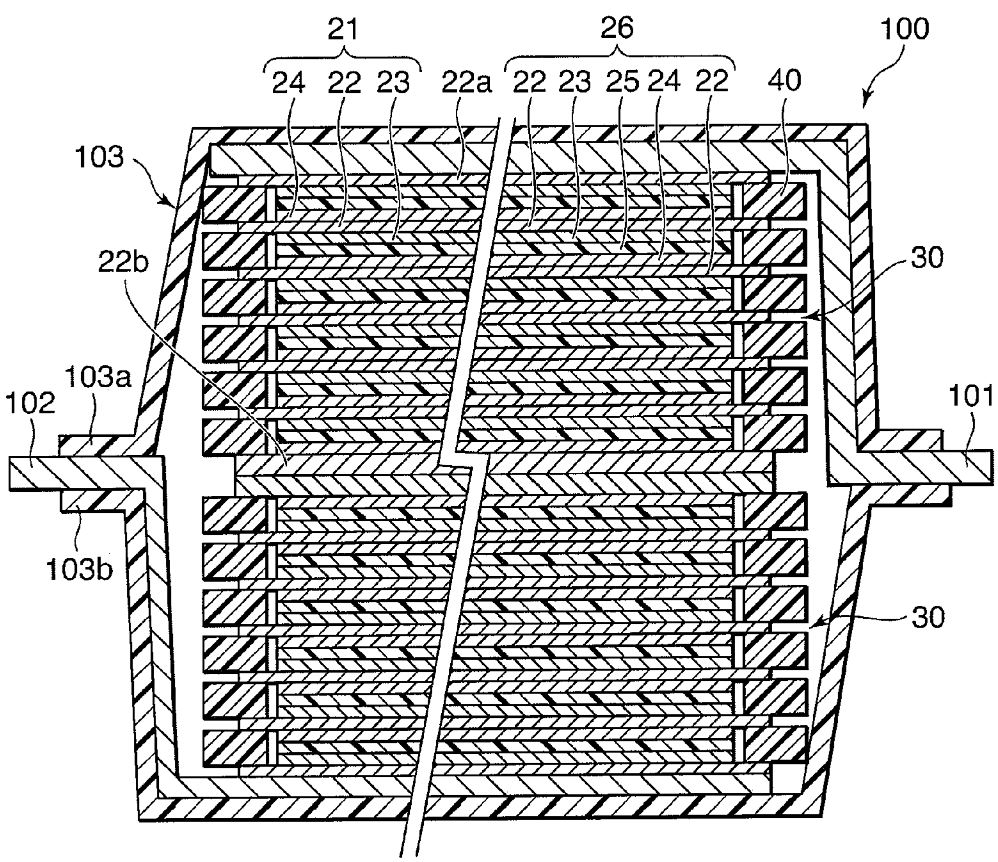
21
26
100
24
22
23
22a
22
23
25
24
22
40
103
22b
30
103a
102
101
103b
30

FIG. 2

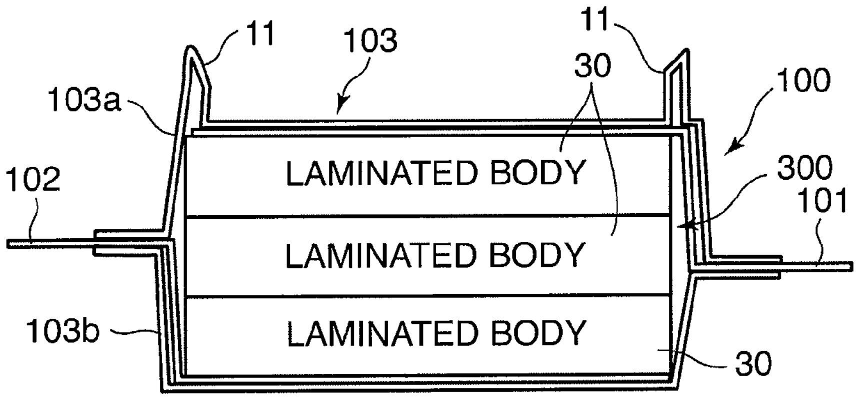

FIG. 3

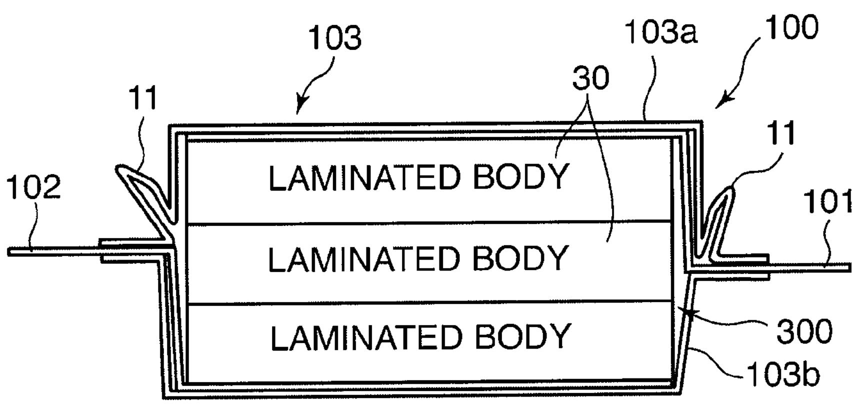

FIG. 4

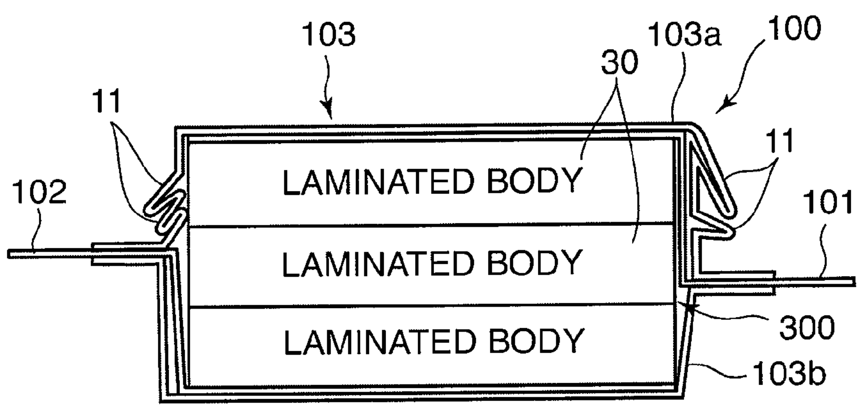

FIG. 5

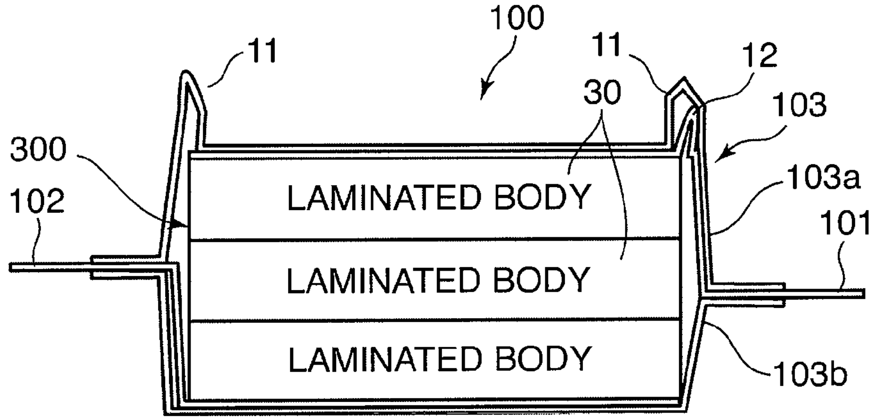

FIG. 6

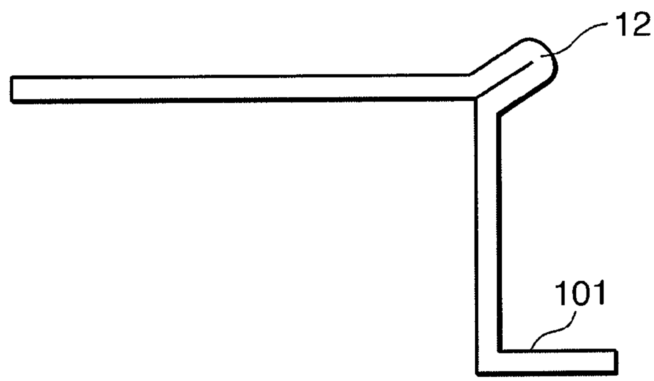

FIG. 7

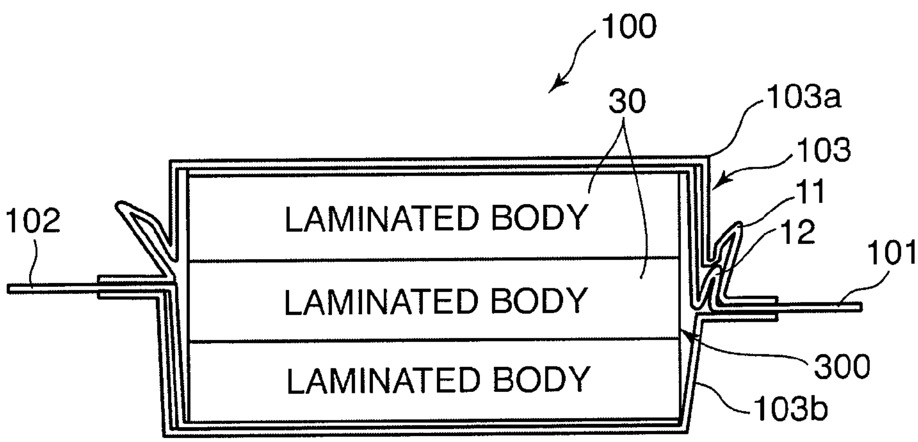

FIG. 8

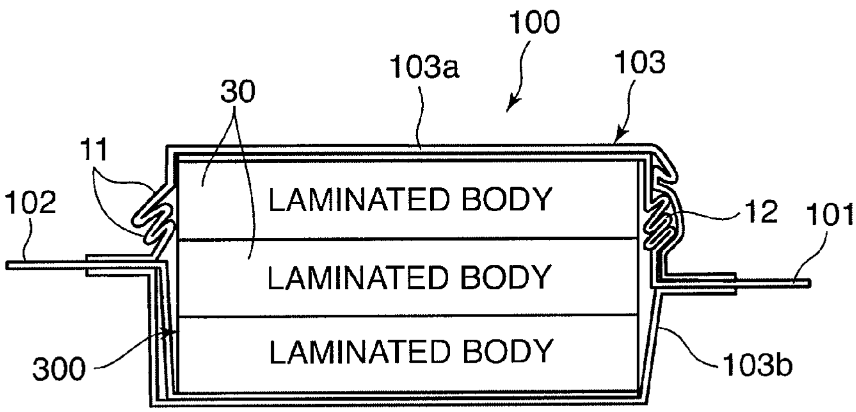
100
103a
103
30
11
102
LAMINATED BODY
12
101
LAMINATED BODY
LAMINATED BODY
300
103b

FIG. 9

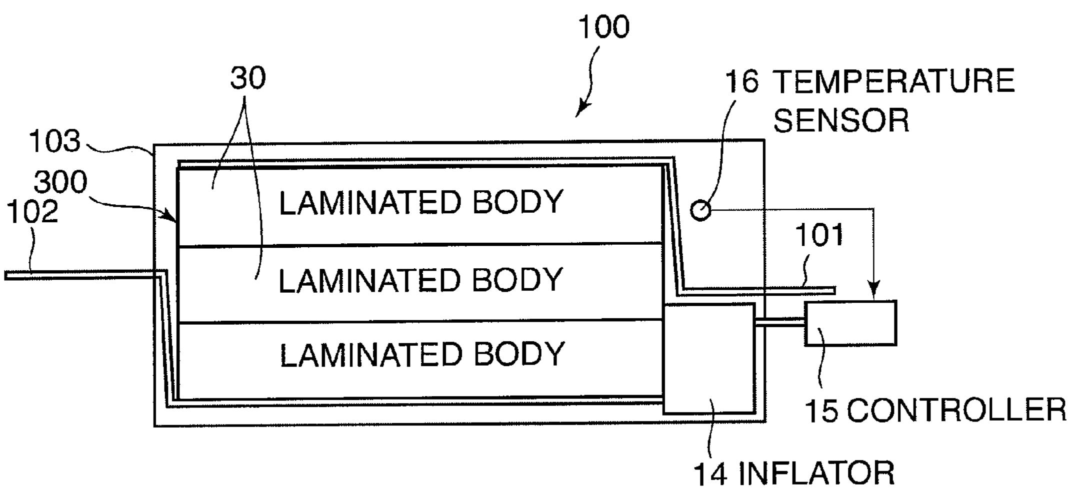
100
30
16 TEMPERATURE SENSOR
103
300
102
LAMINATED BODY
101
LAMINATED BODY
LAMINATED BODY
15 CONTROLLER
14 INFLATOR

FIG. 10

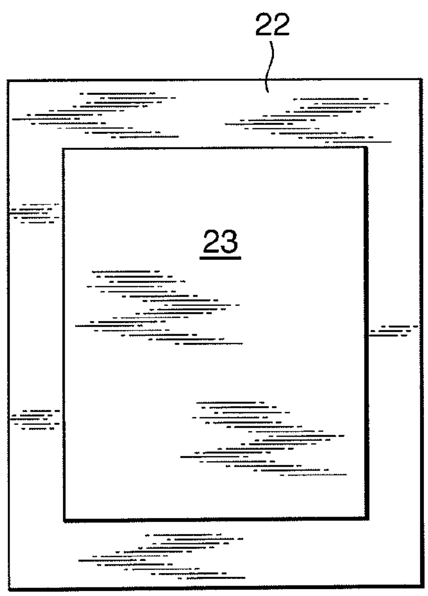

FIG. 11A

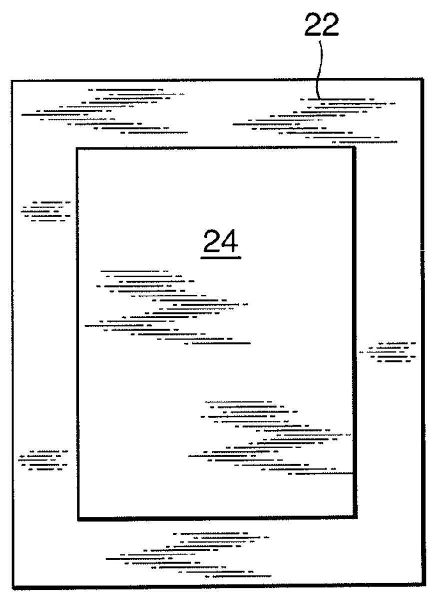

FIG. 11B

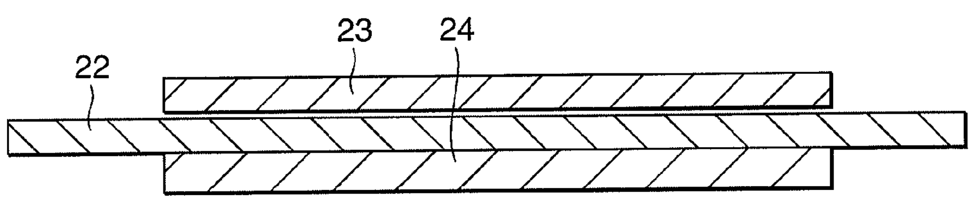

FIG. 11C

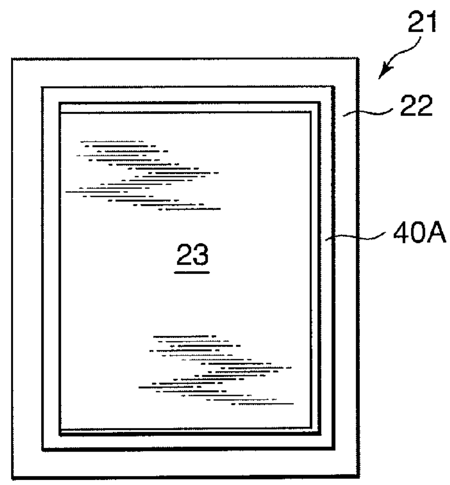

FIG. 12A

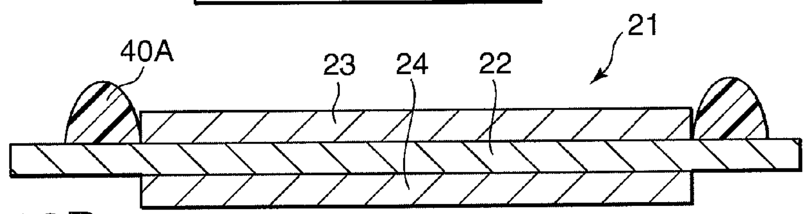

FIG. 12B

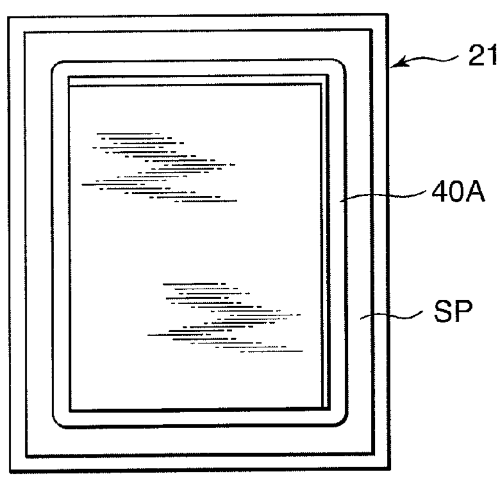

FIG. 13A

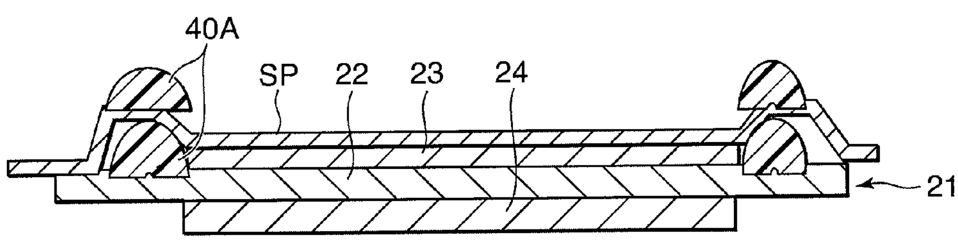

FIG. 13B

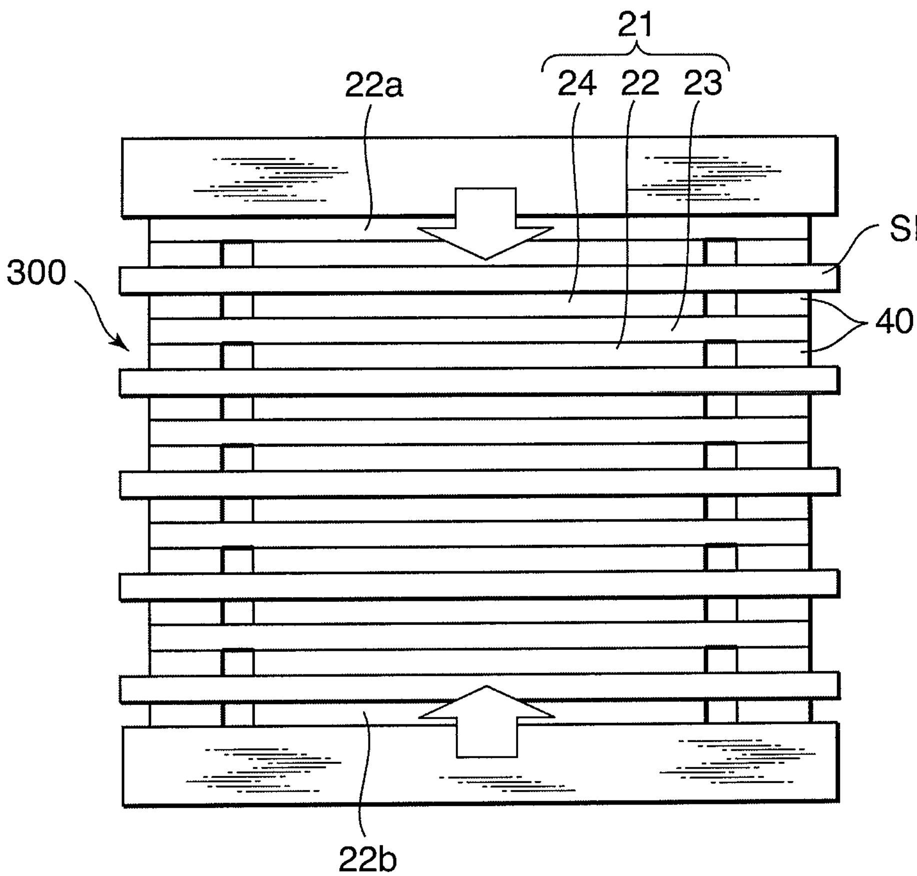
21
24
22
23
22a
SP
300
40
22b

FIG. 14

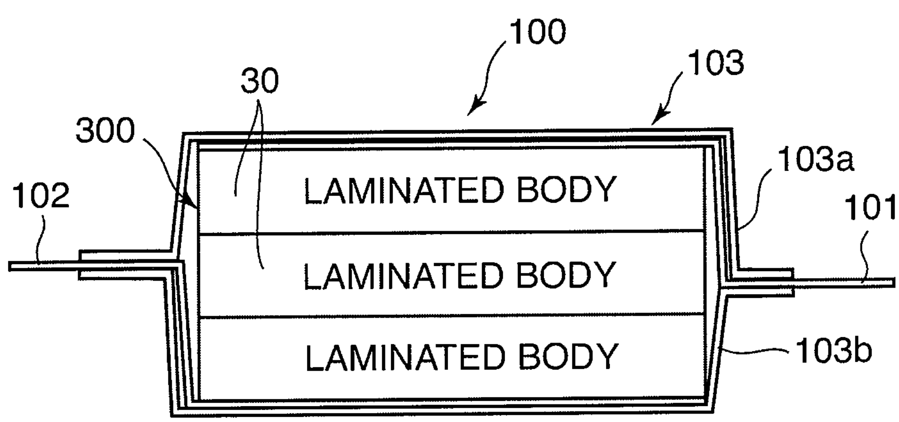
100
103
30
300
103a
102
101
LAMINATED BODY
LAMINATED BODY
LAMINATED BODY
103b

FIG. 15

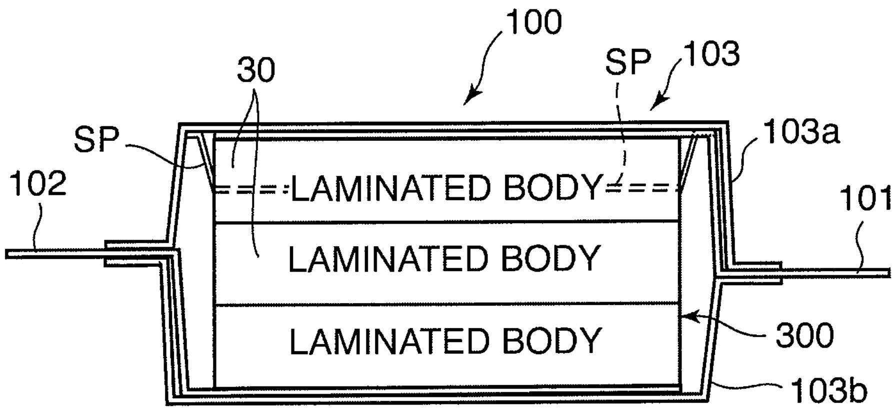
100
SP
103
30
103a
SP
LAMINATED BODY
102
101
LAMINATED BODY
LAMINATED BODY
300
103b

FIG. 16

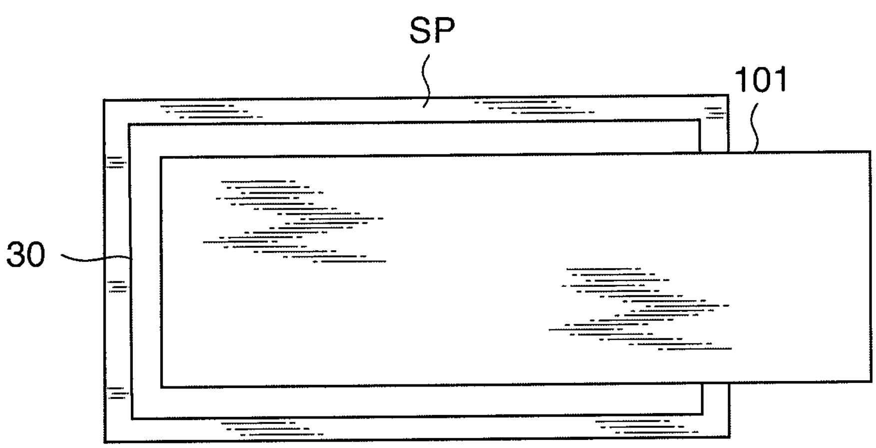
SP
101
30

FIG. 17

BIPOLAR SECONDARY BATTERY

FIELD OF THE INVENTION

This invention relates to protection of a bipolar secondary battery from a short-circuit current.

FIELD OF THE INVENTION

JP2009-252548A published by the Japan Patent Office in 2009 makes a proposal on a fluidity sealant used in a bipolar secondary battery such as a lithium-ion battery composed of a plurality of laminated layers of cells.

A positive electrode active material is arranged at one end of a lamination direction of the cells and a negative electrode active material is arranged at another end. The fluidity sealant is arranged around electrolytes so that the electrolytes of the cells are not degraded due to moisture in the air, and functions to block the cells from the air.

A fluidity sealant such as paraffin undergoes electrolysis under a high voltage. The electrolyzed fluidity sealant can no longer keep a required insulation property. The prior art technology realizes an electrolysis resistant structure by dividing the fluidity sealant into a plurality of sealed layers to prevent the application of a high voltage to the fluidity sealant.

SUMMARY OF THE INVENTION

If an external circuit connected to a bipolar secondary battery is shorted, a short-circuit current continues to flow in the battery and the battery produces heat.

The bipolar secondary battery according to the prior art technology produces an effect of preventing a high voltage load on the fluidity sealant even in such a situation, but does not act to interrupt a short-circuit current and prevent the battery from generating heat.

It is therefore an object of this invention to protect a bipolar secondary battery from a short-circuit current.

In order to achieve the above object, a bipolar secondary battery according to this invention comprises a battery main body, a case for housing the battery main body inside, a positive electrode current collecting plate having one surface joined to an inner peripheral surface of the case and another surface joined to one end of the battery main body and extending to an outside of the case and a negative electrode current collecting plate having one surface joined to the inner peripheral surface of the case and another surface joined to another end of the battery main body and extending to the outside of the case.

The battery main body comprises one laminated body or a plurality of laminated bodies connected in series. The laminated body is formed by laminating a plurality of bipolar electrodes and electrolyte layers alternately. Each of the bipolar electrodes comprises a plate-like current collector, a positive electrode active material layer arranged on one surface of the current collector and a negative electrode active material layer arranged on another surface of the current collector,

The bipolar secondary battery further comprises a cutoff mechanism for cutting off an electrical connection between the positive electrode current collecting plate and the negative electrode current collecting plate via the battery main body according to an expansion deformation of the case.

The details as well as other features and advantages of this invention are set forth in the remainder of the specification and are shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a bipolar secondary battery according to this invention;

FIG. **2** is a longitudinal sectional view of the bipolar secondary battery taken along a line II-II in FIG. **1**;

FIG. **3** is a schematic longitudinal sectional view of a bipolar secondary battery according to a second embodiment of this invention;

FIG. **4** is similar to FIG. **3**, but shows a variation relating to folded portions;

FIG. **5** is similar to FIG. **3**, but shows another variation relating to the folded portions;

FIG. **6** is similar to FIG. **3**, but shows a third embodiment of this invention;

FIG. **7** is a longitudinal sectional view of a current collecting plate according to the third embodiment of this invention;

FIG. **8** is similar to FIG. **6**, but shows a variation relating to folded portions;

FIG. **9** is similar to FIG. **6**, but shows another variation relating to the folded portions;

FIG. **10** is a schematic construction diagram including a schematic longitudinal sectional view of a bipolar secondary battery according to a fourth embodiment of this invention;

FIGS. **11**A to **11**C are a front view, a rear view and a longitudinal sectional view of a bipolar electrode according to this invention;

FIGS. **12**A and **12**B are a front view and a cross-sectional view of a bipolar electrode mounted with a seal precursor;

FIGS. **13**A and **13**B are a front view and a cross-sectional view of a bipolar electrode mounted with a separator;

FIG. **14** is a schematic side view of a press machine showing a final formation process of a bipolar secondary battery;

FIG. **15** is a longitudinal vertical sectional view of a bipolar secondary battery formed with no folded portion;

FIG. **16** is a longitudinal vertical sectional view of a bipolar secondary battery according to a fifth embodiment of this invention; and

FIG. **17** is a plan view of an interior of the bipolar secondary battery according to the fifth embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1** of the drawings, a bipolar secondary battery **100** comprises a case **103** having a substantially rectangular horizontal section and a positive electrode current collecting plate **101** and a negative electrode current collecting plate **102** taken out from the inside of the case **103** through two opposite sides of the case **103**.

Referring to FIG. **2**, the bipolar secondary battery **100** comprises a battery main body **300** inside the case **103**. The battery main body **300** is formed by connecting two laminated bodies **30**, in which a plurality of cells **26** is laminated, in series. The positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** are respectively joined to the inner peripheral surface of the case **103** while sandwiching the battery main body **300**. More specifically, the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** are fixed to the inner peripheral surface of the case **103** by bonding.

The case **103** functions to shut off the battery main body **300** from ambient air, thereby protecting the battery main body **300**. The case **103** is composed of a pair of case members **103***a* and **103***b*. Each of the case members **103***a*, **103***b* comprises a recessed portion for housing the battery main body **300** and a flange portion surrounding the recessed portion.

The case **103** is integrally formed by welding the flange portions of the pair of case members **103***a* and **103***b* while sandwiching the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** extending from the inside of the case **103** to the outside thereof. The case **103** is made of a sheet-like material having such strength as not to damage the laminated bodies **30** against a pressure difference produced between the inside and the outside of the case **103** while having deformable flexibility. It is desirable that the sheet-like material does not allow electrolytic solutions and gases to permeate, has an electrical insulation property and is chemically stable against materials such as electrolytic solutions.

Preferably, a laminated film, polyethylene, polypropylene, polycarbonate or the like is used as the sheet-like material. The laminated film is such that a metal foil of a metal including an alloy of aluminum, stainless steel, nickel, copper or the like is covered with an insulating synthetic resin film such as a polypropylene film.

The cell **26** constituting the laminated body **30** is composed of an electrolyte layer **25**, a positive electrode active material layer **23** and a negative electrode active material layer **24** laminated on opposite sides of the electrolyte layer **25**, and plate-like current collectors **22** laminated on the outer sides of the positive electrode active material layer **23** and the negative electrode active material layer **24** in a lamination direction. It should be noted that, when laminating the plurality of cells **26** as shown in the figure, only one current collector **22** is sandwiched between the adjacent cells **26**.

A known material is used for the current collector **22**. For example, aluminum or stainless steel (SUS) can be used. The material of the current collector **22** may contain a polymer material. That is, polyolefin (polypropylene, polyethylene), polyester (PET, PEN), polyimide, polyamide and polyvinylidene fluoride (PVdF) can be used. To provide these polymer materials with electrical conductivity, particles of carbon such as Ketjen Black, acetylene black or carbon black or of a metal such as aluminum (Al), copper (Cu), stainless steel (SUS) or titanium (Ti) are preferably dispersed in the polymer material.

The positive electrode active material layer **23** comprises a positive electrode active material and can further comprise a conductive assistant, a binder, etc. A complex oxide of a transition metal and lithium used in a solution lithium-ion battery may be used as the positive electrode active material.

The negative electrode active material layer **24** comprises a negative electrode active material and can further comprise a conductive assistant, a binder, etc. A negative electrode active material used in a solution lithium-ion battery may be used as the negative electrode active material.

Particularly, it is possible to form a battery with excellent capacity and output characteristic by using a lithium-transition metal complex oxide as the positive electrode active material of the positive electrode active material layer **23** and using a carbon or lithium-transition metal complex oxide as the negative electrode active material of the negative electrode active material layer **24**.

The electrolyte layer **25** is a layer or a liquid electrolyte including an ion-conducting polymer. In this embodiment, a polymer gel electrolyte obtained by impregnating a separator as a base material with a pre-gel solution and then applying chemical crosslinking or physical crosslinking is used as the electrolyte. An electrolytic solution included in the electrolyte contains an organic solvent such as polyprene carbonate, ethylene carbonate or diethyl carbonate, and boils and gasifies with an increase in temperature. In this embodiment, a melting point of the separator is about 120° C. A boiling point of the electrolytic solution is about 140° C.

The outer periphery of the cell **26** is covered by a seal portion **40**. The seal portion **40** is filled between outer peripheral parts of the adjacent current collectors **22** and blocks the contact of the positive electrode active material layer **23**, the electrolyte layer **25** and the negative electrode active material **24** with ambient air. The seal portion **40** prevents a reduction in the ion-conductivity of the electrolyte by sealing the cell **26**. Further, in the case where a liquid or semisolid gel is used for the electrolyte, the seal portion **40** prevents a short circuit that may be caused by a leaked liquid or gel.

A thermally fusible resin such as a rubber-based resin which adheres to the current collector **22** by being pressed and deformed or an olefin-based resin which adheres to the current collector **22** by being thermally fused through heating and pressing can be used as a seal precursor.

The rubber-based resin is not particularly limited, but preferably selected from a group including silicon-based rubber, fluorine-based rubber, olefin-based rubber and nitrile-based rubber. These rubber-based resins are excellent in sealing performance, alkali resistance, chemical resistance, durability, weather resistance, heat resistant, etc. and these excellent properties and qualities can be maintained for a long period of time under the use environments of secondary batteries.

The thermally fusible resin should also have an excellent sealing performance under every use environment of the laminated body **30**. Preferably, it is selected from silicon, epoxy, urethane, polybutadiene, olefin-based resin (polypropylene, polyethylene, etc.) and paraffin wax, for example. These thermally fusible resins are excellent in sealing performance, alkali resistance, chemical resistance, durability, weather resistance, heat resistant, etc. and these excellent properties and qualities last for a long period of time under the use environments of secondary batteries.

In a production process of the laminated body **30**, a plurality of bipolar electrodes **21** in each of which the positive electrode active material layer **23** is formed on one surface of the current collector **22** and the negative electrode active material **24** is formed on the other surface and a plurality of electrolyte layers **25** are alternatively laminated over six layers. A positive electrode current collector **22***a* and a negative electrode current collector **22***b* are laminated on opposite ends of the laminated body **30** in the lamination direction. Different from the current collector **22**, the positive electrode active material layer **23** is formed on one surface of the positive electrode current collector **22***a*, but nothing is formed on the other surface thereof. The negative electrode active material **24** is formed on one surface of the negative electrode current collector **22***b*, but nothing is formed on the other surface thereof. The positive electrode current collector **22***a* is laminated with the positive electrode active material layer **23** held in contact with the electrolyte layer **25**. The negative electrode current collector **22***b* is laminated with the negative electrode active material **24** held in contact with the electrolyte layer **25**.

A predetermined number of cells **26** laminated as described above are thermally pressed using a thermal press machine so that the seal portions **40** have a predetermined thickness, and the uncured seal portions **40** are further cured, whereby the bipolar laminated body **30** is completed.

The battery main body **300** is composed of the two laminated bodies **30** arranged in series such that the positive electrode current collector **22***a* of one laminated body **30** is held in contact with the negative electrode current collector **22***b* of the other laminated body **30**.

The positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** function to take out a current from the case **103** of the battery main body **300** or supply a current to the battery main body **300** from the outside of the case **103**. Materials for the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** are not particularly limited and known materials can be used. Preferably, aluminum, stainless steel (SUS), a polymer material and the like are used.

The adjacent positive electrode current collector **22***a* and negative current collector **22***b* of the two laminated bodies **30** constituting the battery main body **300** are bonded by a conductive adhesive. Further, the positive electrode current collector **22***a* located at one end of the battery main body **300** and the positive electrode current collecting plate **101** are also bonded by the conductive adhesive. The negative electrode current collector **22***b* located at the other end of the battery main body **300** and the negative electrode current collecting plate **102** are also bonded by the conductive adhesive. Any one of a butyl rubber-based conductive double-sided adhesive tape having a peel strength of 120%, an acrylic-based conductive double-sided adhesive tape having a peel strength of 100% and a conductive epoxy adhesive having a peel strength of 90% is used as the adhesive.

Further, the positive electrode current collecting plate **101** is joined to the inner peripheral surface of the case member **103***a* and the negative electrode current collecting plate **102** is joined to the inner peripheral surface of the case member **103***b* by bonding using an adhesive. A butyl rubber-based double-sided adhesive tape having a peel strength of 120% or an acrylic-based double-sided adhesive tape having a peel strength of 100% is used for bonding.

Each peel strength expresses the peel strength of each adhesive in percentage when the peel strength of the acrylic-based double-sided adhesive tape is 100%.

It is not an essential requirement to bond the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30** and these may be merely held in contact without being bonded.

In the bipolar secondary battery **100** according to this invention, the above bonding is so performed as to satisfy the following conditions.

Providing that K4 denotes the peel strength between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30**, K3 denotes the peel strength between the positive electrode current collector **22***a* and the positive electrode current collecting plate **101**, K5 denotes the peel strength between the negative electrode current collector **22***b* and the negative electrode current collecting plate **102**, K1 denotes the peel strength between the positive electrode current collecting plate **101** and the case **103** and K2 denotes the peel strength between the negative electrode current collecting plate **102** and the case **103**, any of the following conditions should be satisfied

$$K1,K2>K3 \text{ or}$$

$$K1,K2>K4 \text{ or}$$

$$K1,K2>K5.$$

It should be noted that the peel strength K4 equals zero when the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30** are not adhered.

The above relationship is expressed by the following sentence. Specifically, the peel strength between the inner peripheral surface of the case **103** and the positive electrode current collecting plate **101** and the peel strength between the inner peripheral surface of the case **103** and the negative electrode current collecting plate **102** are both higher than at least one of the peel strength between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a*, the peel strength between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* and the peel strength between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies **30**.

The bipolar secondary battery **100** is completed by fusing the flange-like outer peripheral parts of the pair of case members **103***a*, **103***b* constituting the case **103** in a vacuum state after the above process. The interior of the case **103** may be left in a vacuum state by fusing the outer peripheral parts of the case members **103***a*, **103***b* excluding parts thereof and sucking air in the case **103** through an unfused part.

In a hybrid electric vehicle (HEV) or an electric vehicle (EV), various electrical circuits, which operate on power supplied from a vehicle-mounted battery, may experience a trouble when a strong impact is applied to a vehicle body. If power continues to be supplied from the battery to the faulty circuit, an excessive current flows into the faulty circuit, the circuit produces heat and a high-current line may be shorted. High-current lines in the vehicle-mounted battery may also be shorted to each other.

In such a case, an excessive short-circuit current flows in the bipolar secondary battery **100** and the temperature of the bipolar secondary battery **100** increases due to heat generation caused by an internal resistance of the bipolar secondary battery **100**. If an organic solvent such as polyprene carbonate, ethylene carbonate or diethyl carbonate included in the electrolytic solution of the electrolyte layers **25** of the laminated bodies **30** boils and gasifies with this increase in temperature, an internal pressure of the case **103** increases and the case **103** expands.

The expansion of the case **103** exerts a tensile load on the two laminated bodies **30** via the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** bonded to the inner peripheral surface of the case **103**.

This tensile load acts as a peel force not only between the inner peripheral surface of the case **103** and the positive electrode current collecting plate **101** and between the inner peripheral surface of the case **103** and the negative electrode current collecting plate **102**, but also between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30**, between the positive electrode current collector **22***a* located at the one end of the battery main body **300** and the positive electrode current collecting plate **101** and between the negative electrode current collector **22***b* located at the other end of the battery main body **300** and the negative electrode current collecting plate **102**.

In this bipolar secondary battery **100**, the peel strength between the inner peripheral surface of the case **103** and the positive electrode current collecting plate **101** and the peel strength between the inner peripheral surface of the case **103** and the negative electrode current collecting plate **102** are both set to be higher than at least one of the peel strength between the positive electrode current collector **22***a* at the one end of the battery main body **300** and the positive electrode current collecting plate **101**, the peel strength between the negative electrode current collector **22***b* at the other end of the battery main body **300** and the negative electrode current collecting plate **102** and the peel strength between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30**.

Thus, by the action of the peel force, any one pair of the positive electrode current collecting plate **101** and the positive electrode current collector **22***a*, the negative electrode current collecting plate **102** and the negative electrode current collector **22***b*, the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30** constituting the battery main body **300** are peeled off from each other. The contact between these peeled members is weakened, whereby the flow of the short-circuit current is suppressed. Further, when the members are completely peeled off from each other, the short-circuit current is interrupted.

In this way, according to this invention, the bipolar secondary battery **100** is protected from a short-circuit current from the external circuit connected to the bipolar secondary battery **100**.

In this embodiment, each laminated body **30** is composed of six cells and the battery main body **300** is constructed by connecting the two laminated bodies **30** in series. However, the number of the cells **26** constituting the laminated body **30** and the number of the laminated bodies **30** connected in series can be arbitrarily set according to a voltage and a capacity required for the bipolar secondary battery **100**.

Accordingly, the battery main body **300** may be, for example, composed of a single laminated body **30** so that there is no connecting part between the laminated bodies **30**. In such a case, the peel strength between the inner peripheral surface of the case **103** and the positive electrode current collecting plate **101** and the peel strength between the inner peripheral surface of the case **103** and the negative electrode current collecting plate **102** may be both set to be higher than at least one of the peel strength between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300** and the peel strength between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**.

Referring to FIGS. **3**-**5**, a second embodiment of this invention will be described. It should be noted that essential parts in these figures are drawn in a deformed manner to clearly show characteristics.

In the first embodiment, the bipolar secondary battery **100** is so structured that the peel force is generated exclusively by the thermal expansion of the case **103**. In this embodiment, one case member **103***a* constituting a case **103** is provided with folded portions **11** as an allowance for elongation of the case **103** so that the case **103** expands in a lamination direction of cells **26** according to a gas pressure increase in the case **103**.

Referring to FIG. **3**, the folded portion **11** is formed into a cylindrical shape projecting in a direction away from a battery main body **300** from an end surface of the case member **103***a* in the lamination direction of the cells **26**. The projecting end is then folded back by substantially 180° to form a crest portion. The folded portion **11** facilitates an expansion deformation of the case **103** by displacing the end surface of the case member **103***a* at the inner side of the folded portion **11** in the direction away from the battery main body **300** according to an increase in the internal pressure of the case **103**.

The configuration of a bipolar secondary battery **100** other than the case **103** is the same as in the first embodiment, including the setting of peel strengths. The expansion of the case **103** in response to an internal pressure increase is facilitated by this embodiment. As a result, when the internal pressure of the case **103** increases, the peeling of any one of the pairs of a positive electrode current collecting plate **101** and a positive electrode current collector **22***a* at one end of the battery main body **300**, a negative electrode current collecting plate **102** and a negative electrode current collector **22***b* at the other end of the battery main body **300** and a positive electrode current collector **22***a* and a negative electrode current collector **22***b* between two laminated bodies **30** constituting the battery main body **300** is promoted.

Thus, the bipolar secondary battery **100** can be more quickly and more reliably protected against a short-circuit current caused by an external circuit.

Various variations are possible for the formation position and the number of the folded portion **11**.

Referring to FIG. **4**, a folded portion **11** including a crest portion is provided over 360° on the outer peripheral surface of the one case member **103***a* of the case **103** with respect to the lamination direction of the cells **26**.

Referring to FIG. **5**, two folded portions **11** including a crest portion are provided over 360° on the outer peripheral surface of the one case member **103***a* of the case **103** with respect to the lamination direction of the cells **26**.

Regardless of the formation position and the number of the folded portion(s) **11**, if a short-circuit current flows into the bipolar secondary battery **100** to increase the temperature of the battery and the internal pressure of the case **103**, the case **103** thus constructed to expand and contract is easily expanded in the lamination direction of the cells **26**. Preferably, the case **103** is easily deformable without being destroyed at an internal pressure of 0.1 to 10 kg/cm^2 (≅kilopascal (kPa)). If the case **103** is easily deformed at such an internal pressure, the positive electrode current collecting plate **101** or the negative electrode current collecting plate **102** and the battery main body **300**, or the two laminated bodies **30** constituting the battery main body **300** can be easily separated.

That is, if an excessive short-circuit current flows through the external circuit connected to the bipolar secondary battery **100**, the temperature of the bipolar secondary battery **100** increases and the electrolytic solution included in the electrolyte layer **25** of each cell **26** boils. The internal pressure of the case **103** increases due to vapors of the organic solvents produced as the electrolytic solution boils, whereby the case **103** extends in the lamination direction of the cells **26**, i.e. in a direction to extend the folded portion **11**.

As the case **103** extends, the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** bonded to the case **103** by the adhesive having a high peel strength are displaced in directions separating from each other together with the case **103**. This peel force acts between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300**, between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300** and between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30** constituting the battery main body **300**. Since a adhesive force bonding these parts is relatively low, separation occurs between any one of these pairs. As a result, the short-circuit current in the bipolar secondary battery **100** is interrupted.

Although the case member **103***a* is formed with the folded portion **11** in this embodiment, the case member **103***b* may be formed with the folded portion **11**. Both the case member **103***a* and the case member **103***b* may be formed with the folded portion **11**.

Referring to FIGS. **6-9**, a third embodiment of this invention will be described. It should be noted that essential parts in FIGS. **6-9** are drawn in a deformed manner to clearly show characteristics.

Referring to FIG. **6**, further to the configuration of the second embodiment, a length of the positive electrode current collecting plate **101** between a part adhered to the case member **103***a* and the battery main body **300** and a take-out portion according to this embodiment is set to be longer in advance.

Referring to FIG. **7**, specifically, a folded portion **12** is formed in the positive electrode current collecting plate **101** in the section between the part adhered to the case member **103***a* and the battery main body **300** and the take-out portion towards the outside of the case **103**. Further, the location of the folded portion **12** is limited to a position corresponding to a corner part of the battery main body **300**. Preferably, dimensions of the folded portion **12** are set such that a displaceable range of the positive electrode current collecting plate **101** by the folded portion **12** is equal to the range of expansion deformation of the case **103** by the folded portion **11**.

The folded portion **12** is preferably provided at the inner side of the folded portion **11**.

Referring to FIG. **8**, especially when the folded portion **11** is formed on the outer peripheral surface of the case member **103***a*, the folded portion **12** is preferably formed within the folded portion **11**.

Referring to FIG. **9**, when a plurality of folded portions **11** is formed on the outer peripheral surface of the case member **103***a*, a plurality of the folded portions **12** is preferably provided.

The other configuration of the bipolar secondary battery **100** according to this embodiment is the same as in the second embodiment.

In the second embodiment, there is a possibility that a displacement of the positive electrode current collecting plate **101** following an expansion deformation of the case **103** may be restrained due to the dimension of the positive electrode current collecting plate **101** in the lamination direction of the cells **26**. According to this embodiment, however, the positive electrode current collecting plate **101** can be displaced easily, following an expansion deformation of the case **103**, by providing the positive electrode current collecting plate **101** with the folded portion **12**. The positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300**, or the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**, or the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30** constituting the battery main body **300** can thereby be more reliably separated when an expansion deformation of the case **103** occurs.

Although the case member **103***a* is formed with the folded portion **11** and the positive electrode current collecting plate **101** is formed with the folded portion **12** in this embodiment, it is also possible to form the case member **103***b* with the folded portion **11** and form the negative electrode current collecting plate **102** with the folded portion **12**. Further, it also possible to form both the case member **103***a* and the case member **103***b* with the folded portion **11** and form both the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** with the folded portion **12**.

Referring to FIG. **10**, a fourth embodiment of this invention will be described.

A bipolar secondary battery **100** according to this embodiment comprises an inflator **14** for producing gas inside a case **103**.

The inflator **14** produces gas by chemical reaction. The inflator **14** comprises a built-in igniter, firelighter, gas-forming agent, etc. A controller **15** arranged outside the case **103** is connected to the inflator **14**. The controller **15** actuates the igniter of the inflator **14** to ignite the firelighter and burn the gas-forming agent.

As another configuration relating to the inflator **14**, it is also possible to include a built-in high-pressure container filled with high-pressure gas and a built-in actuator for opening the high-pressure container and release the gas in the high-pressure container by the controller **15** arranged outside the case **103** for actuating the actuator. A hybrid type inflator corresponding to a combination of the above two types of the inflator **14** may also be used.

A temperature sensor **16** for detecting a temperature of the laminated bodies **30** is connected to the controller **15**. The controller **15** is constituted by a microcomputer including a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM) and an input/output interface (I/O interface). The controller **15** is pre-programmed to actuate the inflator **14** when the temperature of the laminated bodies **30** becomes, for example, 100° C. or higher.

It is also possible to provide a current sensor for detecting a current in the positive electrode current collecting plate **101** or the negative electrode current collecting plate **102** instead of the temperature sensor **16** and program the controller **15** so as to actuate the inflator **14** when a detected current of the current sensor exceeds a short-circuit current equivalent value.

Further, it is possible to provide a voltage sensor for detecting a voltage difference between the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** instead of the temperature sensor **16** and program the controller **15** so as to actuate the inflator **14** when a detected voltage of the voltage sensor deviates from a voltage value equivalent to the one during a normal operation. The voltage value during the normal operation is, for example, 4.2 V to 2.5 V.

Furthermore, it is possible to provide a pressure sensor for detecting an internal pressure of the case **103** instead of the temperature sensor **16** and program the controller **15** so as to actuate the inflator **14** when the internal pressure of the case **103** becomes equal to or higher than a predetermined pressure.

Any of the above sensors is a sensor for detecting a parameter related to a short-circuit current in the bipolar secondary battery **100**.

According to this embodiment, if a short-circuit current flows into the bipolar secondary battery **100**, the inflator **14** operates to produce gas, whereby the case **103** is expanded by a gas pressure. As a result, the case **103** quickly extends and the positive electrode current collector **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300**, or the negative electrode current collector **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**, or the positive electrode current collector **22***a* and the negative electrode current collector **22***b* of the two laminated bodies **30** constituting the battery main body **300** can be promptly separated.

Referring to FIGS. **16** and **17**, a fifth embodiment of this invention will be described.

In this embodiment, a separator SP which is a base material of an electrolyte layer **25** of any one of cells **26** constituting a battery main body **300** is formed to be larger than external dimensions of the cell **26**, and an outer peripheral part of the separator SP is fused to an end surface of a case member **103***a* inside a case **103**.

To avoid interference with a positive electrode current collector **101**, a cut-out for allowing the passage of the positive electrode current collecting plate **101** is formed in the outer peripheral part of the separator SP. The specification of the case **103** is the same as in the first embodiment.

As the case **103** undergoes an expansion deformation, a laminated body **30** including the separator SP whose outer peripheral part is fixed to the case member **103***a* is displaced integrally with the case member **103**. As a result, a tensile load which acts on the battery main body **300** in association with the expansion deformation of the case **103** acts between this laminated body **30** and a negative electrode current collecting plate **102** fixed to a case member **103***b* in a concentrated manner, thereby promoting the peeling between the positive electrode current collector **22***a* and a negative electrode current collector **22***b* between the laminated bodies **30** or the peeling between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**.

Note that the separator SP may be fixed to an end surface of the case member **103***b*. Further, the separator SP fixed to the case member **103***a* or **103***b* may be included in any cell **26** of any laminated body **30**.

Next, Referring to FIGS. **11**A-**11**C, FIGS. **12**A and **12**B, FIGS. **13**A and **13**B, FIG. **14** and FIG. **15**. an experiment conducted by the inventors on the manufacturing of the bipolar secondary battery **100** and a current interruption capability of the obtained product will be described

First, the fabrication of a bipolar secondary battery will be described.

A positive electrode layer was prepared in the following manner. A positive electrode base including 85 weight percent (wt %) of $LiMn_2O_4$ as a positive electrode active material, 5 wt % of acetylene black as a conductive assistant and 10 wt % of polyvinylidene fluoride (PVdF) as a binder was prepared. By adding N-methylpyrrolidone (NMP) as a slurry viscosity adjusting solvent to the positive electrode base until a viscosity optimal for an application operation was reached, a positive electrode slurry was prepared.

As shown in FIG. **11**A, a positive electrode active material layer **23** of 30 μm was formed by applying the positive electrode slurry to one surface of a SUS foil having a thickness of 20 microns (μm) as a current collector **22** and by drying the positive electrode slurry.

A negative electrode layer was prepared in the following manner. That is, a negative electrode base including 90 wt % of hard carbon as a negative electrode active material and 10 wt % of PVDF as a binder was prepared. By adding NMP as a slurry viscosity adjusting solvent to the negative electrode base until a viscosity optimal for an application operation was reached, a negative electrode slurry was prepared. As shown in FIG. **11**B, a negative electrode active material layer **24** of 30 μm was formed by applying the negative electrode slurry to the opposite surface of the SUS foil as the current collector **22** having the positive electrode applied and by drying the negative electrode slurry.

A base material of a bipolar electrode **21** was obtained by forming the positive electrode active material layer **23** and the negative electrode active material layer **24** on the opposite surfaces of the SUS foil as the current collector **22** as shown in FIG. **11**C.

Subsequently, the base material is cut into a piece of 160×130 mm, and the surfaces of the SUS were exposed by peeling off an outer peripheral part having a width of 10 mm from each of the positive and negative electrodes. As a result, a structure of the bipolar electrode **21** was prepared which comprises electrode surfaces of 140×110 mm and the current collector **22** formed by the exposed SUS having a width of 10 mm at the outer peripheral side of the electrode surfaces.

Subsequently, an electrolyte base including 90 wt % of an electrolytic solution containing 1 moll of lithium hexafluorophosphate (LiPF6) in a mixed solvent of propylene carbonate-ethylene carbonate (PC-EC) and 10 wt % of PVdF-HFP including 10% of a hexafluoropropene (HFP) as a host polymer was prepared. By adding dimethyl carbonate (DMC) as a slurry viscosity adjusting solvent to the electrolyte base until a viscosity optimal for an application operation was reached, a pre-gel electrolyte was prepared. The bipolar electrode **21** soaked with a gel electrolyte was completed by applying this pre-gel electrolyte to the surfaces of the positive and negative electrode parts of the structure and drying the DMC.

Next, fabrication of a seal portion precursor will be described.

Referring to FIGS. **12**A and **12**B, a seal precursor **40**A made of a one-part uncured epoxy resin was applied to the exposed part of the outer peripheral part of the positive electrode of the bipolar electrode **21** using a dispenser.

Referring to FIGS. **13**A and **13**B, a separator SP of 170×140 (mm) made of a polyethylene film having a thickness of 12 μm was arranged on the positive electrode side so as to cover the entire surface of the current collector **22** including the SUS. Thereafter, the seal precursor **40**A made of the one-part uncured epoxy resin was applied to a position of the separator SP to be overlapped with the seal precursor **40**A using the dispenser.

By laminating the bipolar electrodes **21** and the separators SP described above, a structure of the laminated body **30** in which twelve cells **26** are laminated was prepared.

Next, press molding of a bipolar battery will be described.

Referring to FIG. **14**, the seal precursors **40**A were cured to obtain seal portions **40** by thermally pressing the structure of the laminated body **30** constructed as described above with a surface pressure of 1 kg/cm^2 (≅kPa) at 80° C. for one hour by a thermal press machine. In this way, the seal portions **40** can be pressed to a predetermined thickness and can be cured further. As a result of the above process, the laminated body **30** in which twelve layers of cells **26** were laminated was completed.

Next, packaging will be described.

By bonding three laminated bodies **30** formed by the above process to each other using conductive double-sided adhesive tapes, the three laminated bodies **30** connected in series, in other words, a battery main body **300** composed of thirty six layers of cells **26** was obtained. A positive electrode current collecting plate **101** was bonded to a positive electrode current collector **22***a* at one end of the battery main body **300** by a conductive double-sided adhesive tape. A negative electrode current collecting plate **102** was bonded to a negative electrode current collector **22***b* at another end of the battery main body **300**. A surface of the positive electrode current collecting plate **101** opposite to the battery main body **300** was bonded to the inner peripheral surface of a case member **103***a* using a double-sided adhesive tape. Similarly, a surface of the negative electrode current collecting plate **102** opposite to the battery main body **300** was bonded to the inner peripheral surface of a case member **103***b* by a double-sided adhesive tape. Flange portions of the case members **103***a*, **103***b* were welded to vacuum seal the case **103** with take-out portions of the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** sandwiched between the flange portions.

By the above process, Examples #1 to #8 according to this invention relating to the bipolar secondary battery **100** and Comparative Examples #1 to #3 not according to this invention were prepared.

Any one of a butyl rubber-based conductive double-sided adhesive tape having a peel strength of 120%, an acrylic-based conductive double-sided adhesive tape having a peel strength of 100% and an epoxy adhesive having a peel strength of 90% was used for bonding between the positive electrode current collecting plate **101** and the case member **103***a* and between the negative electrode current collecting plate **102** and the case member **103***b*.

Further, any one of a butyl rubber-based conductive double-sided adhesive tape having a peel strength of 120%, an acrylic-based conductive double-sided adhesive tape having a peel strength of 100% and an epoxy adhesive having a peel strength of 90% was used for bonding between the positive electrode current collectors **22***a* and the negative electrode current collectors **22***b* between two adjacent ones of the three laminated bodies **30**, between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300** and between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**. Any of the peel strengths expresses a relative peel strength in percentage when the peel strength of the acrylic-based double-sided adhesive tape is 100%.

The specification of each part of Examples #1 to #8 and Comparative Examples #1 to #3 on the peel strength is shown in TABLE-1. Note that Examples #1 to #4 correspond to the first embodiment, Example #5 corresponds to the second embodiment, Example #6 corresponds to the third embodiment, Example #7 corresponds to the fourth embodiment and Example #8 corresponds to the fifth embodiment.

TABLE 1

		Peel Strength (%)						
Name	Case	Positive Electrode Current Collecting Plate/Positive Electrode Current Collector	Positive Electrode Current Collector/ Negative Electrode Current Collector	Negative Eectrode Current Collecting Plate/Negative Electrode Current Collector	Positive Electrode Current Collecting Plate/Case	Negative Electrode Current Collecting Plate/Case	Separator/ Case	Battery Shape
Comparative Example #1	Aluminum laminated film	100	100	100	90	90		FIG. 15
Comparative Example #2	Aluminum laminated film	100	100	100	120	90		"
Comparative Example #3	Aluminum laminated film	100	100	100	90	120		"
Example #1	Aluminum can	100	90	100	120	120		"
Example #2	Aluminum laminated film	100	90	100	100	100		"
Example #3	Aluminum laminated film	100	120	120	120	120		"
Example #4	Aluminum laminated film	100	100	90	100	100		"
Example #5	Aluminum laminated film	100	90	100	100	100		FIG. 3
Example #6	Aluminum laminated film	100	90	100	100	100		FIG. 6
Example #7	Aluminum laminated film	100	90	100	100	100		FIG. 10
Example #8	Aluminum laminated film	100	90	100	100	100	120	FIGS. 16, 17

In Comparative Examples #1 to #3 not according to this invention, the acrylic-based conductive double-sided adhesive tape having a peel strength of 100% is used for bonding between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies L constituting the battery main body **300**, between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300** and between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**.

In Comparative Example #1, the epoxy adhesive having a peel strength of 90% is used for bonding between the positive electrode current collecting plate **101** and the case member **103***a* and between the negative electrode current collecting plate **102** and the case member **103***b*. In Comparative Example #2, the butyl rubber-based double-sided adhesive tape having a peel strength of 120% is used for bonding between the positive electrode current collecting plate **101** and the case member **103***a* and the epoxy adhesive having a peel strength of 90% is used for bonding between the negative electrode current collecting plate **102** and the case member **103***b*. In Comparative Example #3, the epoxy adhesive having a peel strength of 90% is used for bonding between the positive electrode current collecting plate **101** and the case member **103***a* and the butyl rubber-based double-sided adhesive tape having a peel strength of 120% is used for bonding between the negative electrode current collecting plate **102** and the case member **103***b*.

On the other hand, in Examples #1 and #2 according to this invention, the epoxy adhesive having a peel strength of 90% is used for bonding between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies **30** constituting the battery main body **300** and the acrylic-based conductive double-sided adhesive tape having a peel strength of 100% is used for bonding between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300** and between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**.

In Example #1, the butyl rubber-based double-sided adhesive tape having a peel strength of 120% is used for bonding between the positive electrode current collecting plate **101** and the case member **103***a* and between the negative electrode current collecting plate **102** and the case member **103***b*.

In Example #2, the acrylic-based conductive double-sided adhesive tape having a peel strength of 100% is used for bonding between the positive electrode current collecting plate **101** and the case member **103***a* and between the negative electrode current collecting plate **102** and the case member **103***b*.

In Example #3 according to this invention, the butyl rubber-based double-sided adhesive tape having a peel strength of 120% is used for bonding between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies **30** constituting the battery main body **300**, the acrylic-based conductive double-sided adhesive tape having a peel strength of 100% is used for bonding between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300**, the butyl rubber-based double-sided adhesive tape having a peel strength of 120% is used for bonding between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**, and the butyl rubber-based double-sided adhesive tape having a peel strength of 120% is used for bonding between the positive electrode current collecting plate **101** and the case member **103***a* and between the negative electrode current collecting plate **102** and the case member **103***b*.

In Example #4 according to this invention, the acrylic-based conductive double-sided adhesive tape having a peel strength of 100% is used for bonding between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies **30** constituting the battery main body **300** and between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300**, the epoxy adhesive having a peel strength of 90% is used for bonding between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300** and the acrylic-based conductive double-sided adhesive tape having a peel strength of 100% is used for bonding between the positive electrode current collecting plate **101** and the case member **103***a* and between the negative electrode current collecting plate **102** and the case member **103***b*.

In Examples #5 to #8 according to this invention, the epoxy adhesive having a peel strength of 90% is used for bonding between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies **30** constituting the battery main body **300**, and the acrylic-based conductive double-sided adhesive tape having a peel strength of 100% is used for bonding between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300**, between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300**, between the positive electrode current collecting plate **101** and the case member **103***a* and between the negative electrode current collecting plate **102** and the case member **103***b*.

Further, in Example #8 according to this invention, the separator SP of a specific cell **26** is formed to have large external dimensions, and the outer peripheral part of this separator SP is bonded to the case member **103***a* via the butyl rubber-based double-sided adhesive tape having a peel strength of 120%.

Next, differences in the material and the shape of the case **103** and the presence or absence of the inflator **14** will be described.

The case **103** of Example #1 is formed of an aluminum alloy can and the cases **103** of Comparative Examples #1 to #3 and Examples #2 to #7 are formed of an aluminum laminated film.

The cases **103** of the bipolar secondary batteries **100** of Examples #1 to #4 and #8 and Comparative Examples #1 to #3 are formed to have a shape shown in FIG. **15**. This is basically equivalent to the case **103** of the first embodiment.

The case **103** of the bipolar secondary battery **100** of Example #5 is formed to have a shape shown in FIG. **3**. That is, a folded portion **11** projecting in the lamination direction of the cells **26** and including one crest portion is provided at each of both ends of the top surface of one case member **103***a*.

The bipolar secondary battery **100** of Example #6 is formed to have a shape shown in FIGS. **6** and **7**, or in other words the case **103** as in Example #5 is used and a folded portion **12** is formed inside a folded portion **11**.

The case **103** of Example #7 comprises an inflator **14** in the case **103** as shown in FIG. **10** and comprises a controller **15** outside the case **103**.

The inventors connected pipes for feeding air under pressure to the cases **103** of Comparative Examples #1 to #3 and the cases **103** of Examples #1 to #6, fed air under pressure while measuring an electrical resistance between the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** and measured internal pressures of the cases **103** when the electrical resistance increased. Concerning Example #7, an internal pressure of the case **103** when an electrical resistance between the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** suddenly increased was measured in a state where the inflator **14** arranged in the case **103** was actuated.

Measurement results for Comparative Examples #1 to #3 and Examples #1 to #6 and #8 are shown in TABLE-2.

collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300** and the peel strength between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies **30** constituting the battery main body **300**. That is to say, the bonded part having a weakest peel strength is present between the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102**. Therefore, if the case **103** extends, peeling occurs somewhere between the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** and a short-circuit current in the bipolar secondary battery **100** is interrupted.

It can be understood from the results of Examples #2 to #4 that at least one of the peel strength between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300**, the peel strength between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300** and the peel strength between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies **30** has to be below the peel strength between the positive electrode current collecting plate **101** and the case **103** and the peel strength between the negative electrode current collecting plate **102** and the case **103**. It is understood that a current is interrupted by increasing the internal pressure of the case **103** in this way.

TABLE 2

Item	Comparative Example #1	Comparative Example #2	Comparative Example #3	Example #1	Example #2	Example #3	Example #4	Example #5	Example #6	Example #8
Resistance Sudden Increase	Absent	Absent	Absent	Present	Present	Present	Present	Present	Present	Present
Internal Pressure (kg/cm^2) (≅kPa)				12 (Case Broken)	8	9	8	4	1	8
Peel Position	Negative Current Collecting Plate/Case	Negative Current Collecting Plate/Case	Positive Current Collecting Plate/Case	Positive Current Collector/ Negative Current Collector	Positive Current Collector/ Negative Current Collector	Positive Current Collecting Plate/ Positive Current Collector	Positive Current Collector/ Negative Current Collector	Positive Current Collector/ Negative Current Collector	Positive Current Collector/ Negative Current Collector	Positive Current Collector/ Negative Current Collector

With reference to TABLE-1, in Comparative Examples #1 to #3 not according to this invention, the peel strength between the positive electrode current collecting plate **101** and the case **103** and the peel strength between the negative electrode current collecting plate **102** and the case **103** are lower than any of the peel strength between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300** or the peel strength between the negative electrode current collecting plate **102** and the negative electrode current collector **22***b* at the other end of the battery main body **300** or the peel strength between the positive electrode current collector **22***a* and the negative electrode current collector **22***b* between the laminated bodies **30**. Thus, peeling occurs between the positive electrode current collecting plate **101** and the case **103** or between the negative electrode current collecting plate **102** and the case **103**, and a short-circuit current in the bipolar secondary battery **100** cannot be interrupted.

In Examples #1 to #6 and #8 according to this invention, the peel strength between the positive electrode current collecting plate **101** and the case member **103***a* and the peel strength between the negative electrode current collecting plate **102** and the case member **103***b* are higher than at least one of the peel strength between the positive electrode current collecting plate **101** and the positive electrode current collector **22***a* at the one end of the battery main body **300**, the peel strength between the negative electrode current

The comparison of Example #1 and Examples #2 with #6 and #8 shows that the resistance suddenly increased at an internal pressure of 12 kg/cm^2 (≅kPa), but simultaneously the case **103** was broken due to the internal pressure in Example #1. From this fact, a possibility of breaking the case **103** due to the internal pressure is thought to be high when the case **103** is not deformed even if the internal pressure reaches 10 kg/cm^2 (≅kPa) or higher.

The comparison of Examples #2 to #4 and #8 with Examples #5, #6 shows that the case **103** is not formed with the folded portion **11** corresponding to an allowance for elongation for a volume change in Examples #2 to #4 and #8. In such cases, it is not possible to interrupt power unless a relatively large internal pressure is applied.

Further, it is understood from the comparison of Example #5 with Example #6 that a current can be interrupted by a smaller internal pressure by forming the folded portion **11** and the folded portion **12** than in the case of forming only the folded portion **11**.

Concerning Example 7 not shown in TABLE-2, the electrical resistance between the positive electrode current collecting plate **101** and the negative electrode current collecting plate **102** suddenly increased as in other Examples #1 to #6 when the controller **15** actuated the inflator **14** to apply an internal pressure of 5 kg/cm^2 (≅kPa) to the case **103**. Accordingly, it was confirmed that an internal current of the bipolar secondary battery **100** could be interrupted.

It was confirmed from Examples #1 to #8 that the short-circuit current could be easily interrupted by using the case **103** made of the laminated film such as an aluminum laminated film.

The contents of Tokugan 2010-115113, with a filing date of May 19, 2010 in Japan, are hereby incorporated by reference.

Although the invention has been described above with reference to certain embodiments, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, within the scope of the claims.

For example, this invention is also applicable to any bipolar secondary battery including lithium-ion batteries.

In each of the embodiments described above, the sealed case **103** is obtained by welding the case members **103***a*, **103***b* made of aluminum cans or aluminum laminated films to each other. However, the case **103** may have any structure and may be made of any material as long as the case **103** has a property to extend according to a temperature increase.

INDUSTRIAL FIELD OF APPLICATION

As described above, it is possible according to this invention to interrupt the flow of a large amount of current into a bipolar secondary battery. This produces a preferable effect in protecting a secondary battery of an electric vehicle.

The embodiments of this invention in which an exclusive property or privilege is claimed are defined as follows:

The invention claimed is:

1. A bipolar secondary battery, comprising:

a battery main body including one laminated body or a plurality of laminated bodies connected in series, the laminated body comprising a plurality of bipolar electrodes and electrolyte layers laminated alternately in a lamination direction, the bipolar electrode comprising a plate-like current collector, a positive electrode active material layer arranged on one surface of the current collector and a negative electrode active material layer arranged on another surface of the current collector;

a case formed of a sheet-like case member and housing the battery main body;

a positive electrode current collecting plate having one surface joined to an inner peripheral surface of the case and another surface joined to one end of the battery main body, the positive electrode current collecting plate extending to an outside of the case;

a negative electrode current collecting plate having one surface joined to the inner peripheral surface of the case and another surface joined to another end of the battery main body, the negative electrode current collecting plate extending to an outside of the case; and

a cutoff mechanism configured to cut off an electrical connection between the positive electrode current collecting plate and the negative electrode current collecting plate by exerting a tensile load there-between in response to an expansion deformation of the case,

wherein the positive electrode current collecting plate and the negative electrode current collecting plate are on opposite ends of the battery main body in the lamination direction, and

wherein the cutoff mechanism comprises a folded portion constituted by the case member bent in inward and outward directions of the case and configured to unfold and expand the case primarily in the lamination direction according to a gas pressure increase in the case.

2. The bipolar secondary battery as defined in claim **1**, wherein the cutoff mechanism is configured by setting a peel strength between the positive electrode current collecting plate and the inner peripheral surface of the case and a peel strength between the negative electrode current collecting plate and the inner peripheral surface of the case to be higher than at least one of a peel strength between the positive electrode current collecting plate and the battery main body, a peel strength between the negative electrode current collecting plate and the battery main body and a peel strength between the plurality of laminated bodies.

3. The bipolar secondary battery as defined in claim **1**, wherein the inner peripheral surface of the case and the positive electrode current collecting plate, the inner peripheral surface of the case and the negative electrode current collecting plate, the positive electrode current collecting plate and the one end of the battery main body and the negative electrode current collecting plate and the another end of the battery main body are respectively joined by bonding.

4. The bipolar secondary battery as defined in claim **1**, wherein either one of the positive electrode current collecting plate and the negative electrode current collecting plate comprises a folded portion constituted by the positive electrode current collecting plate or the negative electrode current collecting plate bent in the inward and outward directions of the case.

5. The bipolar secondary battery as defined in claim **1**, wherein the case is formed of a laminated film in which a metal foil is covered with a synthetic resin film.

6. The bipolar secondary battery as defined in claim **1**, wherein the electrolyte layers contain an organic solvent that gasifies with an increase in temperature.

7. The bipolar secondary battery as defined in claim **1**, further comprising an inflator that produces a gas inside the case in response to a command input from outside the case.

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